

Web-Based Data Integration and Annotation in the Intensive Care Unit

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*Integrating patient data to facilitate review and annotation is a challenging task in the intensive care unit (ICU), partially due to the wide variety of proprietary systems and types of data involved. This paper describes SIMON-Web, a Java-based user interface to integrate data from an existing bedside monitoring system and a clinical information system (CIS). SIMON-Web displays graphical data from physiologic monitors and other bedside devices as well as information from the clinical laboratory and physician order-entry systems, and allows users to annotate the data using a point-and-click or free-text interface. By continuing to add functionality to SIMON-Web's extensible user interface, we hope to continue to augment and eventually replace manual care provider data charting in the ICU. As of March, 1997, SIMON-Web has been implemented on two bedside personal computer workstations in the cardiac care unit (CCU) at Vanderbilt University Medical Center.**

INTRODUCTION

Computerized data integration in the ICU has potential benefits in areas such as automated decision support, record-keeping, and work management¹⁻³. However, bringing disparate patient care data together on an ICU workstation is difficult due to a number of challenging design objectives including reliability, full integration with the hospital CIS, user-input centered design, and data import from medical devices⁴. Additional design objectives include remote access to the system using a low-cost, platform-independent, user-friendly graphical interface.

Web-based technologies such as Hypertext Markup Language (HTML) and Common Gateway Interface (CGI) programs can help to satisfy some of these criteria⁵, and have been used to develop a remote interface to physiologic monitor data in a neurosurgical ICU⁶. HTML and CGI scripts are well suited to information display and simple data entry.

However, they alone do not currently provide the level of interactivity needed to implement mission-critical interfaces to clinical information systems^{7,8}. As a result, developers of web-based HIS and ICU interfaces are turning to the Java[†] programming language, which allows fully functional programs to be embedded and run as applets within HTML documents. For example, a real time patient monitoring system has been implemented over the world wide web using Java⁹, a task which would have been almost impossible using HTML and CGI technology alone.

This paper describes SIMON-Web, our Java implementation of an ICU clinical data interface which differs from previous work in several important ways. First, in addition to near-real-time display of data from bedside devices and monitors, SIMON-Web provides display of laboratory and physician order data from the CIS. Second, it provides point-and-click as well as free text annotation capabilities. Finally, SIMON-Web is designed to allow easy display of HTML documents and to incorporate additional Java programs as they are written, as we work toward complete on-line charting by care providers in the ICU.

MOTIVATION

Our initial motivation to develop SIMON-Web stemmed from a need to interpret signals obtained from bedside medical devices using the SIMON system. Briefly, SIMON is an intelligent monitoring system capable of interfacing to a variety of medical devices including IV pumps, ventilators, and patient monitors¹⁰, and has been implemented in the cardiac care unit at Vanderbilt University Medical Center (VUMC) since February, 1996. Soon after SIMON was implemented it became apparent that, in order to better understand signal artifacts and develop algorithms for intelligent alarming, extensive documentation of events which affected the monitor data would be required. In addition, to facilitate data

* Project URL: <http://www.vuse.vanderbilt.edu/~simon>

[†] Java, Solaris, and Applet Viewer are registered trademarks of Sun Microsystems.

review and discussion by the project team as well as the clinical staff it was desirable to be able to view the monitor data and annotations over the web.

In June of 1996 Dr. Geissbuhler developed the ART system, which accepts monitor data from SIMON via FTP transfers from the bedside computer every few minutes. ART graphs the monitor data in .GIF images at various time resolutions, and publishes it on the web along with HTML pages containing laboratory data and physician orders. Lab and order information is updated periodically from VUMC's Medical Archival System (MARS) and DB2 mainframe databases. Shortly after ART's implementation we developed a simple web page for free-text note entry using HTML and CGI scripts. In August 1996 it became possible to view bedside device, laboratory, and order-entry data and to make free text annotations all via the World Wide Web.

Since the nursing staff routinely documents the course of patient care, we realized it could be mutually advantageous to develop a system nurses could use to perform documentation electronically. It would facilitate a better understanding of signals from bedside devices, as well as improve at least some of the many charting and recording tasks of the CCU staff, and provide the potential to move to a completely paperless system. With these overall goals in mind, the following set of design considerations was established.

DESIGN CONSIDERATIONS

Since the only real incentive we could offer nurses to use the system was that it made their job easier, our first concern was providing a system that would facilitate documentation of patient care, not hinder it. Practically, this meant that the system could not require nurses to duplicate computer and paper documentation, so we had to be prepared to handle data which was considered part of the patient's electronic medical record. In addition, the system had to integrate well with existing methods of documentation, since we lacked resources to computerize all nurse record keeping for all patients in the CCU at once. Also, the system could not take substantially longer or be more difficult to use than existing methods of documentation, unless the extra effort was justified in terms of benefits immediately realized by the users.

Another design consideration was maintaining compatibility with the target reference architecture

for information infrastructure at VUMC. We knew a priori that it would not be possible to strictly follow the reference architecture due to our limited resources and the state of the infrastructure. However, the significant points of the architecture, especially the concepts of a shared clinical workstation and independence of end-user applications from shared data management¹¹, were considered during the design of SIMON-Web.

Finally, we identified several important design requirements for the graphical user interface (GUI). Since the GUI could not immediately contain all functionality for an ICU clinical interface due to limited resources and the fact that such functionality is difficult to define, it was important to be able to incorporate additional features after implementation with minimal user impact. In addition, since users at VUMC often need to access clinical data from a variety of remote, non-standardized workstations¹², a platform-independent GUI which can run securely over a network is desirable. We also wanted to re-use as much of the existing ART interface as possible to minimize implementation time. Finally, the GUI needed to be flexible, so that different types of users in different environments can each have interface which suits their unique needs.

IMPLEMENTATION

The only platform readily available for implementation was the SIMON bedside system. SIMON currently runs on a 166MHz Intel Pentium-based personal computer under the Solaris⁺ x86 2.5.1 operating system. Given this platform and the design goals, we implemented the system architecture shown in Figure 1. SIMON-Web consists of a GUI client and a server, both written in Java (JDK 1.0) using Sun's Java Workshop 1.0 development environment. The server handles client requests for information, and retrieves ART data in the form of .GIF images corresponding to bedside monitor data from SIMON, and HTML documents containing clinical lab and physician order data from the MARS and DB2 databases, respectively. Data annotations made on the client are passed to the server where they are formatted and put into MARS via the generic interface engine (GIE) for long-term, reliable storage. Both the SIMON-Web client and server currently run on the same system, along with SIMON. All communication is done using various internet protocol (IP) services. File transfer protocol (FTP) is used to transfer files from ART to the SIMON-Web server as they are requested by the

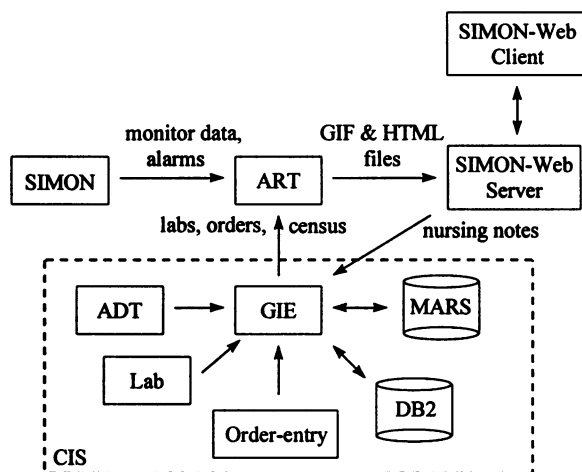


Figure 1: system architecture and relationship to the clinical information system (CIS)

client. Even though they currently run on the same system, communication between the client and server relies on both IP sockets as well as inherent features of the Java language which allow URL's on the server to be accessed by an applet. Socket communication is also used to put data into MARS.

The GUI client is written as a Java applet, and currently runs in Sun Microsystem's Applet Viewer[†]. A sample screen appears in Figure 2, showing how the screen might look after the user has logged into the system and begins annotating the data. Patient information is displayed along the top of the screen, and, depending on system configuration and user rights, different patients may be selected by name, ID, case number, and/or room. The server maintains the census of patients and user rights for browsing.

Below the patient information bar is the main portion of the GUI, where the user reviews and annotates patient data. The "Graph" tab displays .GIF images corresponding to bedside monitor data, and clicking on the image displays a pop-up menu for data annotation. Items in this menu are customizable for individual users, and are downloaded at login. Selecting a descriptive item from the menus pastes that text into the note entry area below for editing or additional description if needed, under a timestamp corresponding to the point which the user clicked on the graph. The menu remains visible until "[DONE]" is clicked, so that multiple events may be noted under

the same timestamp. In addition, the user may elect to paste only a timestamp for free text entry by clicking "Timestamp only".

Navigating forward and backward in time is accomplished by clicking on the arrows on the left and/or right edges of the graph. Data can be viewed at three different resolutions: 24 hours, 1 hour, or 10 minutes per screen. Clicking on the arrow at the top of the graph reduces the resolution, while clicking the graph and selecting "Zoom in" from the menu increases the resolution at that point. Except for the zoom function, this navigation emulates that of the ART system.

Users may also view current lab results, physician orders, or notes that have been entered by clicking on the appropriate tab. This information is displayed in a Java HTML viewer which occupies roughly the same area of the graph image. Currently there is no interactive annotation of lab or order information.

Below the main data display area are the note entry and system panels. The note entry panel contains the text of the current note, which may be edited by the user at any time, as well as buttons for submitting and clearing the note. In addition, the user may add a timestamp corresponding to the current time by clicking on the "Timestamp Now" button. This displays the selection menu for adding items under the timestamp, if the user desires. The system panel contains the controls for logging in and out of the system, as well as a button to send free-text feedback notes to the design team.

As of July 1997, SIMON-Web has been implemented on two bedside computers in the CCU at VUMC. The system has been used by five different nurses to record nursing care notes in over twenty 12-hour shifts. At the end of each shift notes are printed and included in the paper flowchart, since the majority of the flowchart is still paper-based. Each of these nurses was trained to use the system in under 15 minutes. Users seem to appreciate the ability to check laboratory and order data at the bedside, and have minimal difficulty using the system. One user perceived overall time savings in using the system, because the additional time required to type progress notes was offset by time savings in having lab and order data available in the room. Users have also provided useful feedback about the design of the GUI.

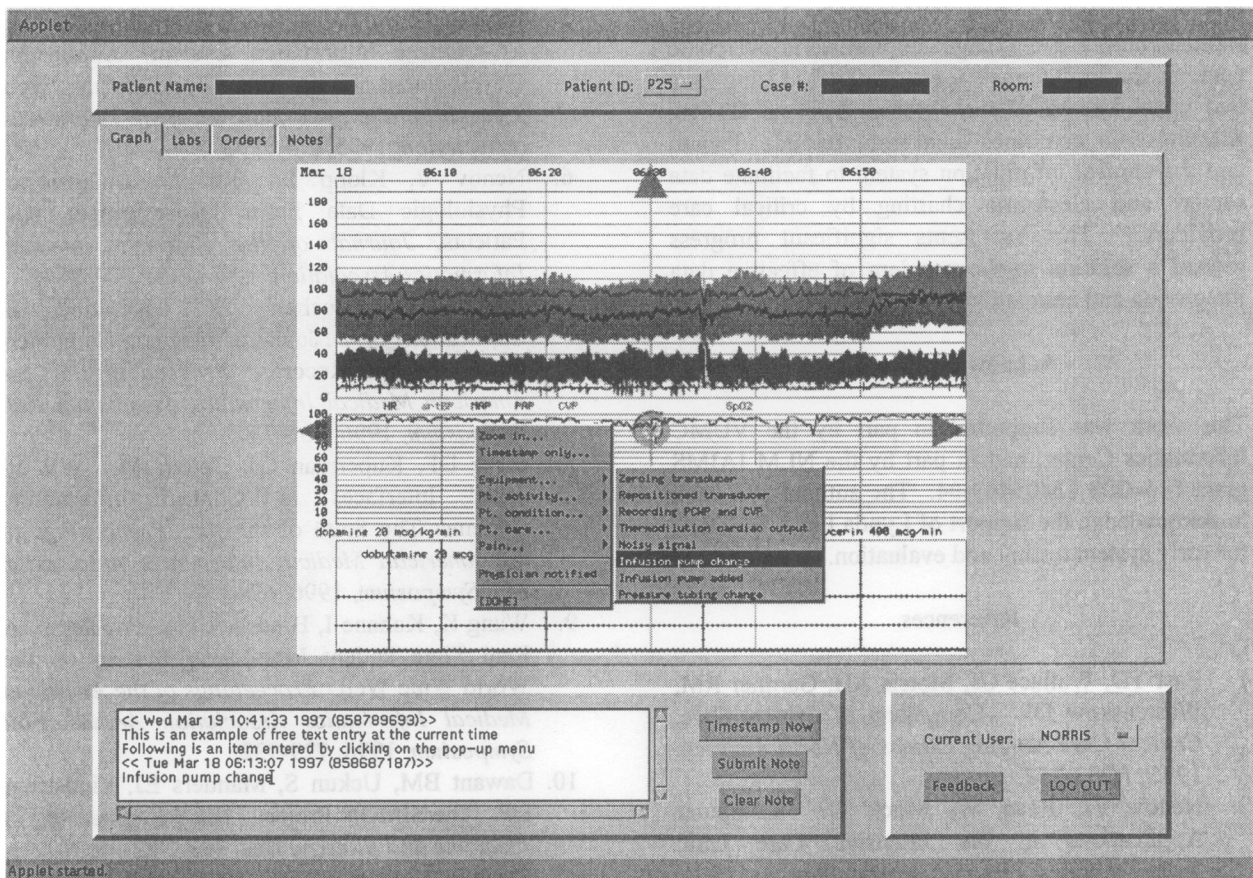


Figure 2: SIMON-Web user interface

DISCUSSION

We are continuing clinical trials of SIMON-Web which will enable us to better assess the system with respect to our overall goal of enhancing documentation in the CCU and improving our understanding of bedside device data. Some of the specific design goals have already been achieved. For example, the SIMON-Web GUI allows for annotation and review of a variety of ICU patient information. Data entered can be transferred to a reliable system where it becomes a permanent part of the patient's medical record. The graph panel and HTML viewing panels for labs, notes, and orders allow data generated by ART to be re-used with minimal modification. In addition, the tabbed-panel design allows for easy expansion of the interface by adding additional tab panels if new HTML data becomes available or if Java code is written to allow for additional data interaction. We also achieved user-dependent customization of the GUI to some

extent, through modification of the items in the pop-up menu based on the current user.

We are close to achieving our design goals of a remote GUI compatible with the VUMC reference architecture, but have been slowed in part due to limitations of the Java language and its implementations. Although Java is promoted as being platform independent, there are currently many incompatibilities across various web browsers and operating systems due to different implementations of the language specification. These problems should be resolved as the language matures, but currently the task of porting the applet from Applet Viewer to a web browser platform is non-trivial. In addition, when the client and server begin to operate on different machines additional security concerns may need to be addressed since more data will be passed over the network.

Despite the limitations of Java, it allowed us to address many of our design goals and produce a

working application at the ICU bedside. In addition, rapid advances in the language promise to overcome some of the limitations we encountered. Using Java and other web-based technologies such as HTML, SIMON-Web combines data from bedside devices and the clinical information system to facilitate data review and electronic charting by critical care providers. This represents significant progress toward a solution to the problem of effective data integration and annotation in the ICU.

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